TEMPERATURE CHANGES OF THE HUMAN SKIN IRRADIATED WITH LOW INTENSITY WAVES SEVERAL CENTIMETERS IN LENGTH

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In the last few years a number of works have been published which are devoted to the use of radio waves of the several-centimeter band in medicine and biology. It has been established that these waves are a more effective thermogenic agent than the ultra-short waves widely used in physiotherapy. Together with the thermal effect of waves of several centimeters in length the possibility is assumed of their extrathermal (specific) effect. But there are still too few experimental data to confirm this supposition.

One of the important tasks in studying the biological effect of the several-centimeter waves is an examination of the relationship between thermal effect and the intensity and duration of irradiation. In a great number of the published works, however, such examinations are more often of a qualitative nature. The intensity of the irradiation was only relatively determined—according to the power output of the generator and the distance from the object to the irradiator, while the temperature of the object was measured after irradiation ceased.

The most exact quantitative relationships were obtained in the experimental work of Seguin and Pelletier [4], Boyle et al., [2] and Cook [3].

Employing special apparatus and methods, these authors secured satisfactorily exact dosage of the wave intensity absorbed in the tissues of the object of irradiation as well as temperature measurement during the irradiation process. They established that in irradiation of a part of the human body according to their method the greatest temperature rise is noted on the surface of the skin.*

In our work we measured the skin temperature of a portion of the human body (the shoulder) irradiated with waves of the ten-centimeter band at low intensity in order to determine that minimal intensity at which a temperature increase is still not observed. The establishment of such a threshold intensity according to thermal effect is a matter of practical interest and is necessary in deciding the question of the presence of an extrathermal effect from the several-centimeter waves.

EXPERIMENTAL METHODS

With a few alterations the technique employed in our experiments was that of H. Cook.

Figure 1 contains a simplified diagram of the wave-conducting dosimeter. The several-centimeter waves created by the generator (1) radiate through the wave-conducting tract of the dosimeter which ends in an

* For the research methods and results, cf. A. Pressman, Uspekhi Sovremenoi Biol., Vol. 41, No. 1, pp 40-54(1956).

irradiator horn (5) against which the object being irradiated (6) is pressed. The amount of power delivered to the object is regulated by means of a blade attenuator (2) which absorbs part of the power. Measurement of the power delivered to the object is accomplished with an indicator (3) through delivery of a negligible portion of the power from the wave-conducting tract to a power meter. A special adjusting device (4) compensates for the partial reflection of waves from the object being irradiated and thus guarantees its absorption of practically the entire power output ("adjustment" with the object).

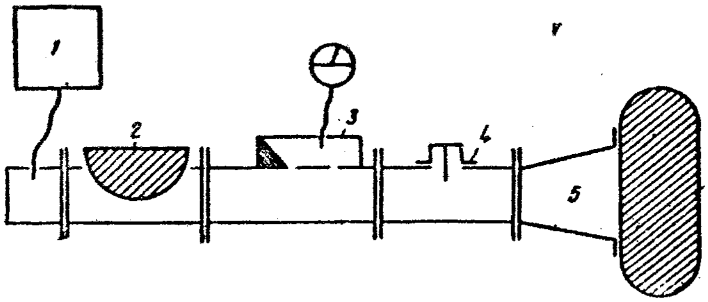

Fig. 1. A simplified diagram of the wave-conducting dosimeter.

The irradiator horn with a mouth area of 40 cm^2 has a flanged rim to which is attached a felt pad treated with aquadag. Such a pad secures good heat insulation of the portion of the body pressed to the rim of the horn from the colder surface of the horn flanges. Considered from another aspect, such a pad eliminates the necessity of pressing the part being irradiated hard against the horn, a practice which can lead to difficulty in blood circulation. Previous research has shown that even when the body part being irradiated is pressed very weakly against the horn through a pad not more than 1% of the power output is absorbed in it.

Measurement of the temperature in the center of the part being irradiated was accomplished with a thermocouple (copper–constantan) on a polystyrene plate fastened across the mouth of the horn perpendicular to the lines of electric force. The junction of the thermocouple was located in the center of the mouth of the horn. The accuracy of the temperature measurements amounted to 0.1°.

The power absorbed by 1 cm^2 of the surface of the object (we called this the "effective intensity") was determined for the central portion of the part being irradiated (where the temperature was measured) in mw/cm^2, with an accuracy of ± 11%. The irradiation was performed with sustained waves 11 cm in length.

The method of irradiation and temperature measurement was as follows:

a) After adaptation to the surrounding temperature the bare arm was placed on a special soft support so that the inner portion of the shoulder pressed lightly against the irradiator horn, thus guaranteeing close contact of the skin surface with the pad on the horn flange along its perimeter. Skin temperature was recorded (in the central portion of the part being irradiated) by means of the thermocouple galvanometer until it finally remained fixed.

b) During delivery of negligible power to the object the adjusting device was set to provide maximal absorption of the power output within the object.*

At the time of the adjustment an observation was made of the skin temperature.

c) After the adjustment the dose attenuator was set to deliver to the object a fixed power (registered on the meter), and the readings of the thermocouple galvanometer were recorded every minute.

The basic experiments were conducted at an air temperature of 19-21°. The subjects of the examinations in all of the experiments were men 28, 29 and 45 years of age.

* Control of the adjustment was accomplished on a guage line (not shown in Fig. 1) by measuring the coefficient of the running wave (CRW), which is characteristic of the degree of power absorption in the object.

RESULTS OF THE EXPERIMENTS

As was pointed out, the main purpose of the experiments was to examine the temperature changes of the skin irradiated with waves several centimeters in length in order to determine the minimal intensity which does not produce a thermal effect. It was therefore necessary, first of all, to select an approximate intensity, maximal for the given experiments. In choosing this intensity we proceeded from the experiments of Cook [3] in which the scarcely endurable intensity amounted to 600-800 mw/cm². We took 35 mw/cm² as our maximal intensity, a value about 20 times smaller than the mean scarcely endurable intensity. The experiments showed that the temperature of skin irradiated at that intensity rises by about 3°.

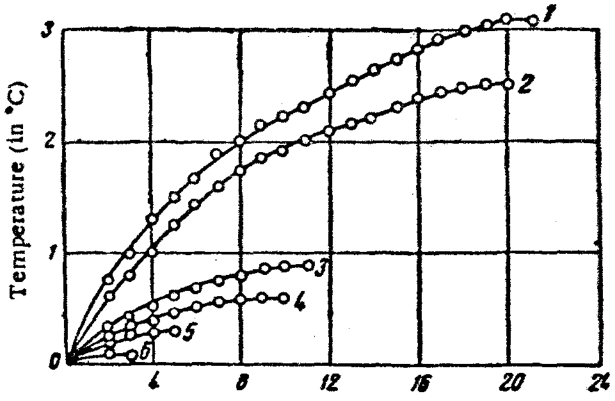

Fig. 2. Rise in temperature of the human skin (the shoulder) irradiated with several-centimeter waves (λ = 11 cm) in relation to duration and intensity of irradiation: 1) 35 mw/cm²; 2) 25 mw/cm²; 3) 20 mw/cm²; 4) 15 mw/cm²; 5) 10 mw/cm²; 6) 5 mw/cm².

An examination was made of normal temperature reactions under the conditions of the experiments. It turned out that over the course of 30 minutes the temperature of the portion of the skin being examined varied within the limits of 0.1°.

A check was also made of the possible change in skin temperature at the time of the adjustment. Within the limits of accuracy of the measurements, no temperature change was detected.

It was also necessary to check whether the thermocouple was heated on account of direct absorption of wave energy.

The experiments showed that no such heating occurs.

In the first series of experiments an examination was made of the relationship between the temperature rise of the portion of the body being irradiated and the duration of irradiation at varying intensity. As is apparent from Fig. 2, according to the extent of irradiation the rise in skin temperature gradually attains a maximum value and is maintained at this level during further irradiation. It is known that the same phenomenon occurs with infrared radiation and is explained by the active incorporation of thermoregulating mechanisms which maintain heat exchange at a definite equilibrium level [1]. Evidently a similar equilibration mechanism takes place in the case being described. Since the maximal temperature rise was observed after approximately 22 minutes of irradiation at the maximal intensity (35 mw/cm²), the duration of irradiation in all of the experiments amounted to 25 minutes.

In the second series of experiments the relationship between change in skin temperature and the average rate of maximal temperature elevation was determined for each intensity. A simultaneous comparison was made of the values of the rise in temperature during irradiation at different intensities for periods of the same duration. The table contains the data of the experiments on irradiation at different intensities at an air temperature of 19-21°. Under these conditions the normal temperature of the portion of the skin of the shoulder under examination amounted to 32-33.9°.

A graph was constructed in accordance with the data of the table. Figure 3 shows how the maximal rise in skin temperature increases with augmentation of the effective intensity. It is evident from Fig. 3 and the table that at an effective intensity of 5 mw/cm² the rise in skin temperature does not exceed 0.1°, while the accuracy of the measurement has the same value; i.e., the skin temperature is practically not increased.

Effective intensity in mw/cm²	Number of experiments	Temperature rise		
		Maximal	After 5 minutes of irradiation	After 11 minutes of irradiation
5	12	0.1° (0–0.2°)	0.1°	0.1°
10	14	0.3° (0.2–0.4°)	0.3°	0.3°
15	14	0.6° (0.5–1.0°)	0.4° (0.3–0.6°)	0.4°
20	13	0.9° (0.6–1.1°)	0.5° (0.4–0.6°)	0.9° (0.6–1.1°)
25	14	2.5° (2.3–2.8°)	1.0° (0.8–1.2°)	1.8° (1.6–2.1°)
35	10	3.1° (2.8–3.5°)	1.3° (1.1–1.5°)	2.3° (1.9–2.8°)

Note: The maximum and minimum values of the individual measurements are indicated in parentheses.

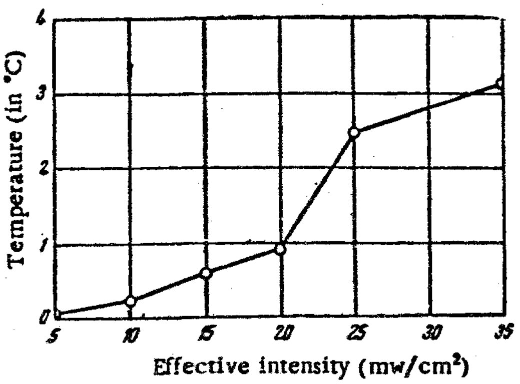

Fig. 3. Maximal rise in temperature of the human skin (the shoulder) irradiated with several-centimeter waves (λ = 11 cm) at different intensities.

On the basis of the results of the experiments the following conclusions can be drawn:

1) During irradiation of a part of the human body (the inner portion of the shoulder) 40 cm² in area with sustained several-centimeter waves (λ = 11 cm) the temperature of the skin increases gradually until reaching a definite (for a given intensity) maximal level and continues to maintain itself at this level during protracted irradiation. This equilibration is apparently explained by the incorporation of thermoregulation mechanisms which maintain heat exchange at a definite equilibrium level (as in the case of infrared radiation).

2) The maximal rise in skin temperature due to irradiation at an effective intensity (that absorbed in the tissues) of 35 mw/cm² amounts on the average to 3.1° (at an air temperature of 19-21°). According to the extent of reduction in intensity, the temperature rise grows steadily smaller, and at an intensity of 5 mw/cm² no rise in skin temperature occurs at all.

3) Under the experimental conditions described (air temperature, 19-21°; λ = 11 cm; surface irradiated, 40 cm²) an effective intensity of 5 mw/cm² can be considered the threshold intensity for the thermal effect of several-centimeter waves.

SUMMARY

Heat effects (temperature rise of the skin) in the tissues of a skin area in man during irradiation with waves (λ = 11 cm) of different intensity (5 mw/cm^2 to 35 mw/cm^2) were studied.

Temperature rise of the skin was found to take place only in the case of the irradiation with waves of an intensity higher than 5 mw/cm^2. Temperature attains its maximum (at a given intensity) in 10 to 25 minutes of irradiation, remaining at this level afterwards.

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* In Russian.